US009274146B2

(12) **United States Patent**
**Boudreau, Jr. et al.**

(10) **Patent No.: US 9,274,146 B2**
(45) **Date of Patent: Mar. 1, 2016**

(54) **ELECTRONIC TAMPER DETECTION IN A UTILITY METER USING MAGNETICS**

(71) Applicant: **Landis+Gyr, Inc.**, Lafayette, IN (US)

(72) Inventors: **Frank J. Boudreau, Jr.**, Otterbein, IN (US); **Matt Kraus**, Jamestown, IN (US)

(73) Assignee: **Landis+Gyr, Inc.**, Lafayette, IN (US)

( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 73 days.

(21) Appl. No.: **14/176,561**

(22) Filed: **Feb. 10, 2014**

(65) **Prior Publication Data**

US 2015/0226769 A1 Aug. 13, 2015

(51) **Int. Cl.**

| | |
|---|---|
| ***G01B 7/14*** | (2006.01) |
| ***G01R 11/24*** | (2006.01) |
| ***G01D 5/20*** | (2006.01) |
| ***G01R 33/07*** | (2006.01) |
| ***G01R 22/06*** | (2006.01) |
| *G01D 4/00* | (2006.01) |

(52) **U.S. Cl.**

CPC .............. ***G01R 11/24*** (2013.01); ***G01D 5/2033*** (2013.01); ***G01R 22/066*** (2013.01); ***G01R 33/07*** (2013.01); *G01D 4/002* (2013.01); *G01D 5/2013* (2013.01)

(58) **Field of Classification Search**

CPC .... G01D 4/002; G01D 5/2033; G01D 5/2013
USPC ................................ 324/207.13, 207.15, 156
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

| | | | | |
|---|---|---|---|---|
| 6,414,475 | B1 * | 7/2002 | Dames et al. | 324/127 |
| 2005/0194962 | A1 * | 9/2005 | Briese et al. | 324/142 |
| 2012/0074927 | A1 | 3/2012 | Ramirez | |

FOREIGN PATENT DOCUMENTS

EP 0447615 A1 9/1991

OTHER PUBLICATIONS

Notification of Transmittal of the International Search Report and the Written Opinion of the International Searching Authority for PCT/US2015/015286, mailed Jun. 19, 2015.

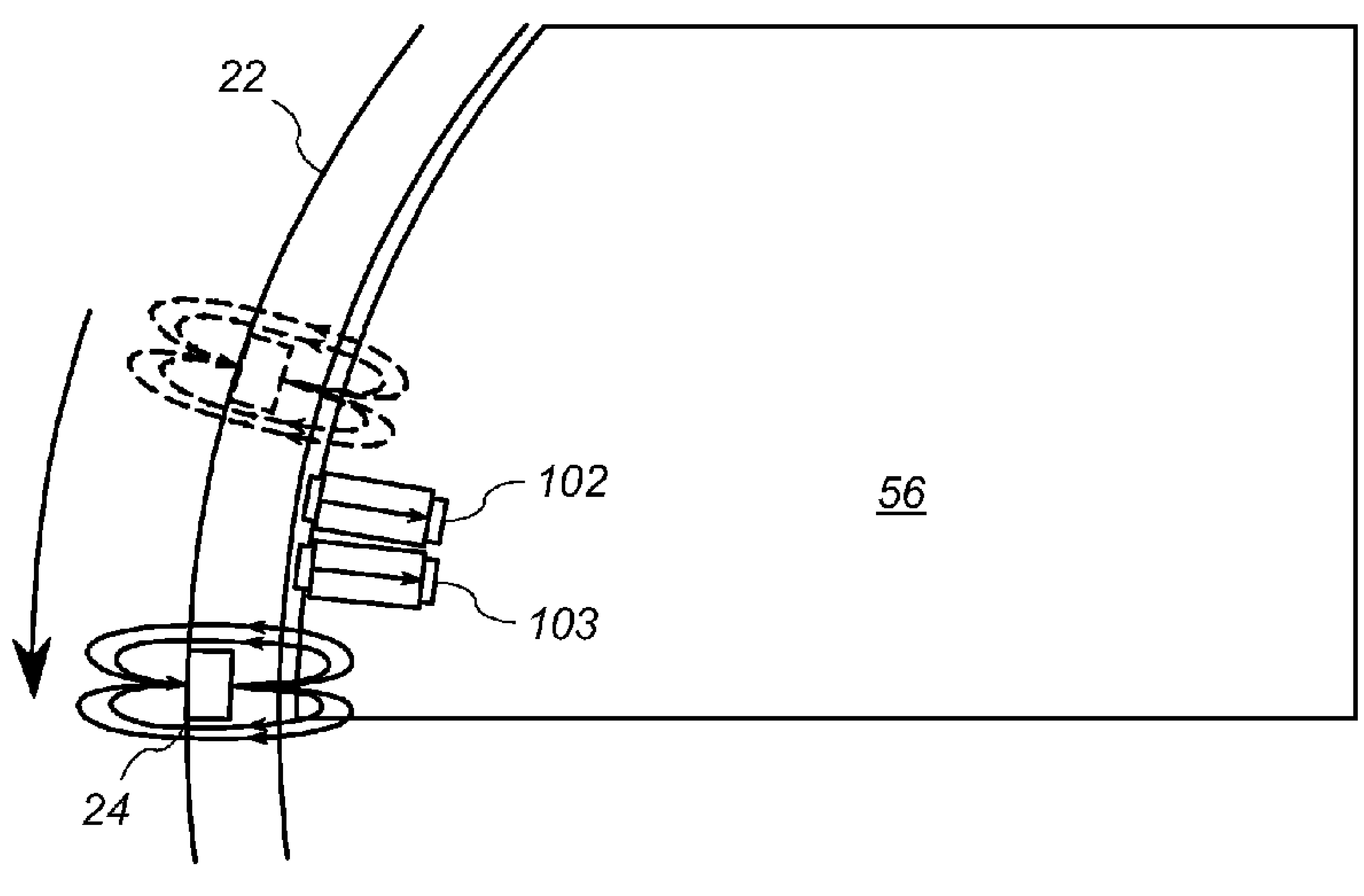
* cited by examiner

*Primary Examiner* — Reena Aurora
(74) *Attorney, Agent, or Firm* — Maginot, Moore & Beck LLP

(57) **ABSTRACT**

An arrangement for use in a utility meter includes a sensor and a processing circuit supported by a base of the meter, and a magnetic element carried by the cover of the meter, in which the cover is removably mounted to the base. The sensor includes at least two magnetizable elements, such as inductors, that are magnetized at opposite polarities when the meter is closed and operable. The magnetizable elements are positioned in very close proximity so that as cover is removed the magnetic element passes the elements to cause the magnetizable elements to assume the same polarity. The processing circuit continuously polls the magnetizable elements to evaluate their respective polarities and is configured to issue a tamper indication when the detected polarities are the same.

**12 Claims, 6 Drawing Sheets**



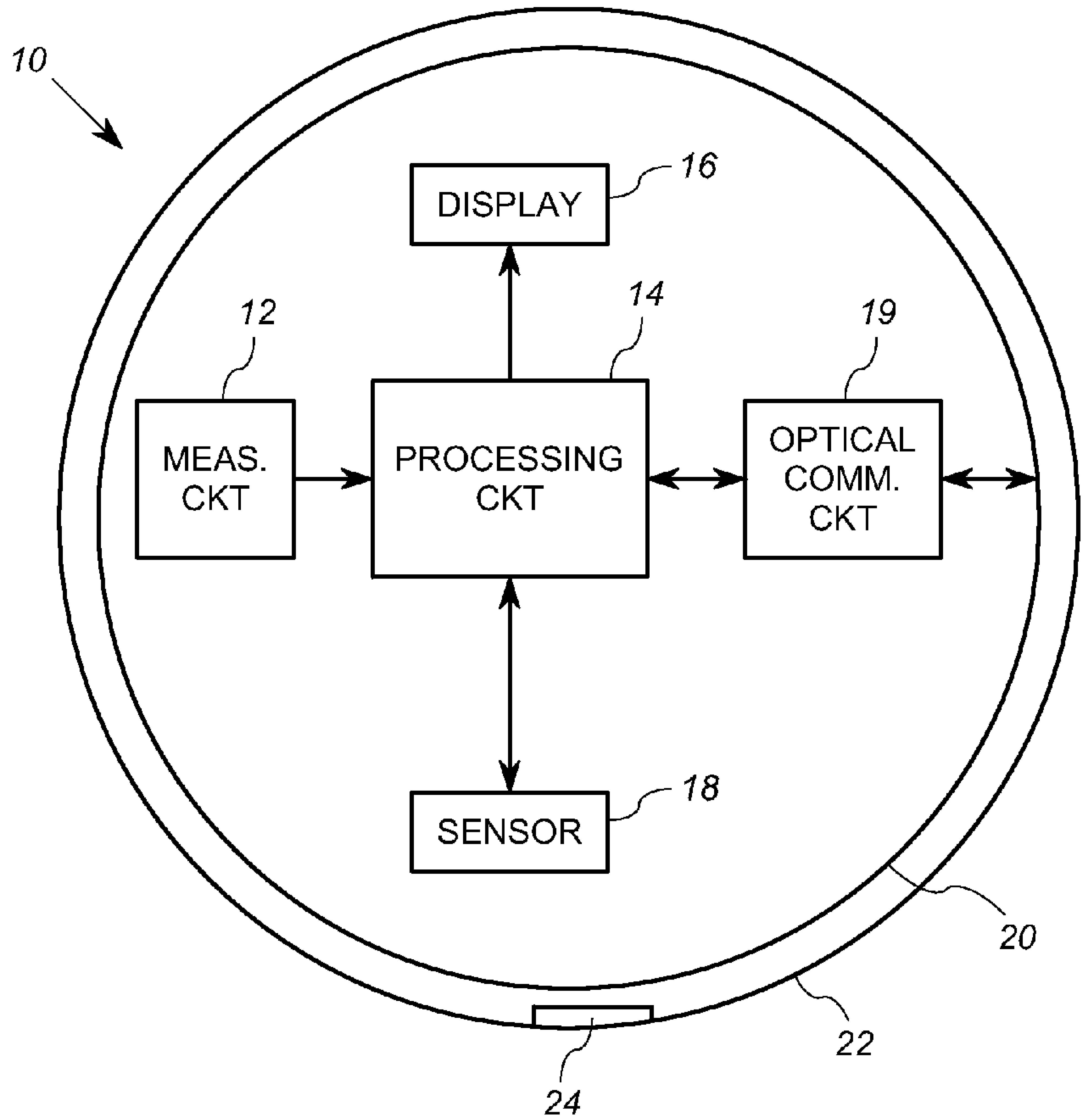



FIG. 1

PRIOR ART

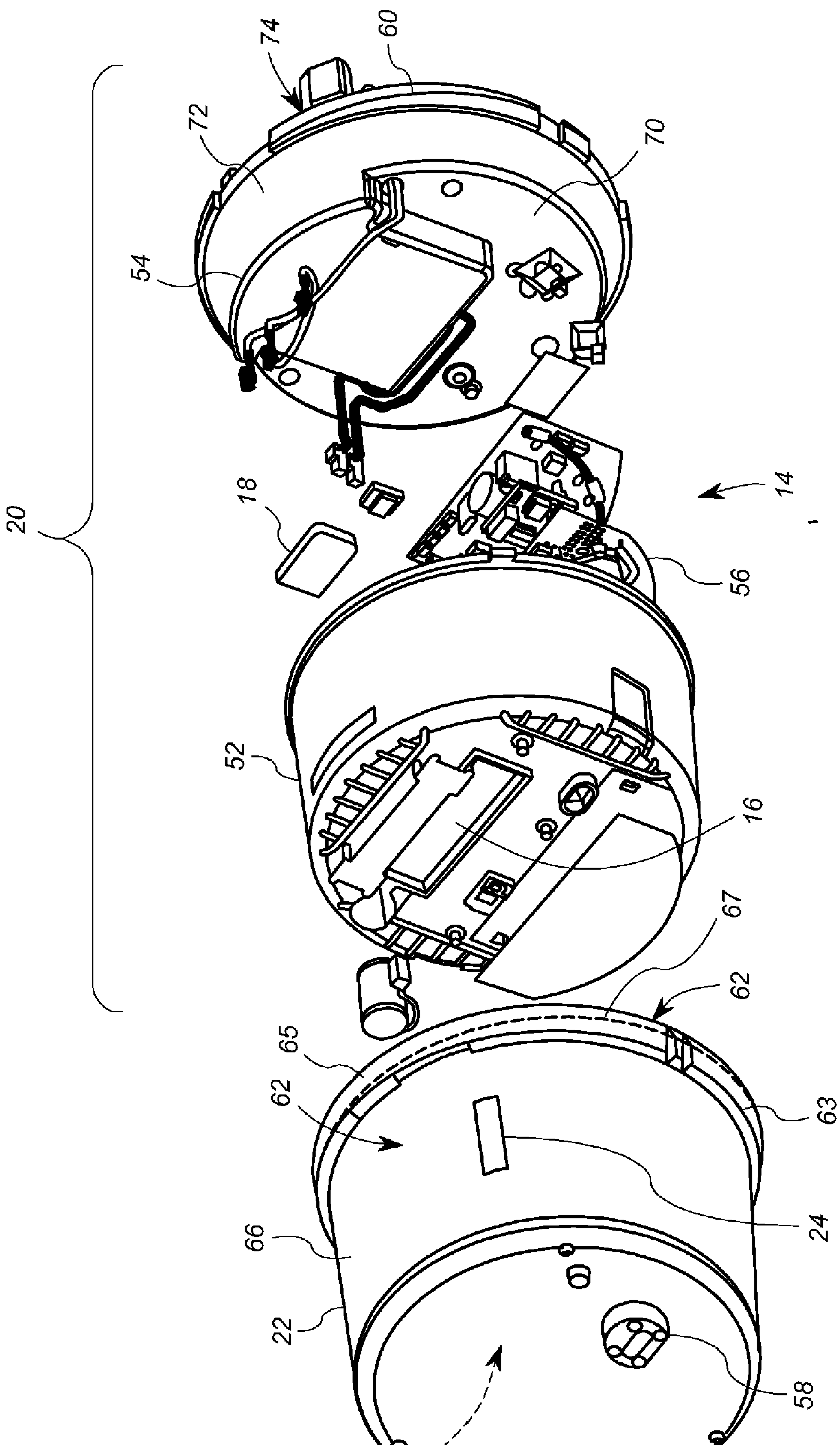



FIG. 2
PRIOR ART

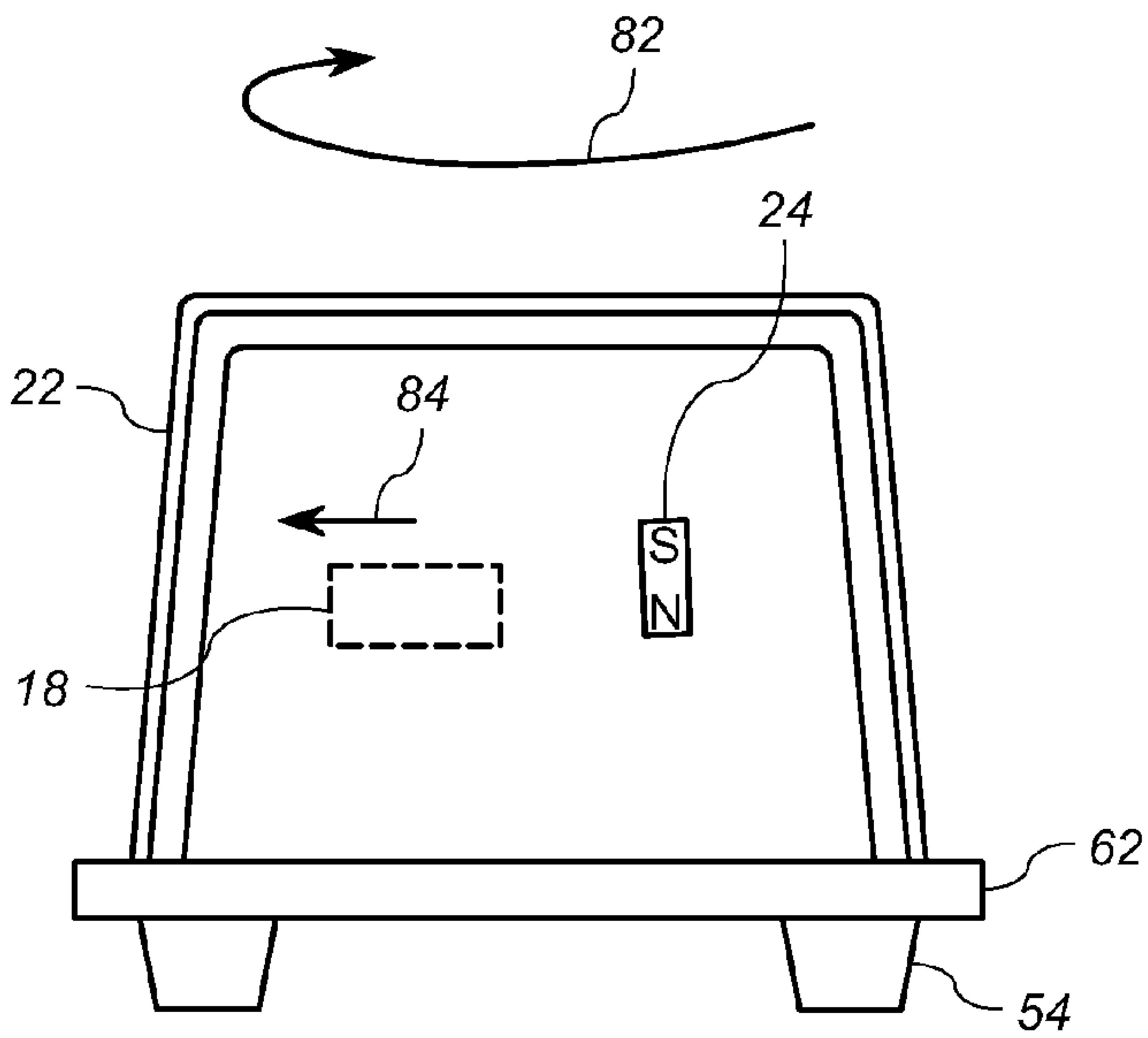



FIG. 3

PRIOR ART

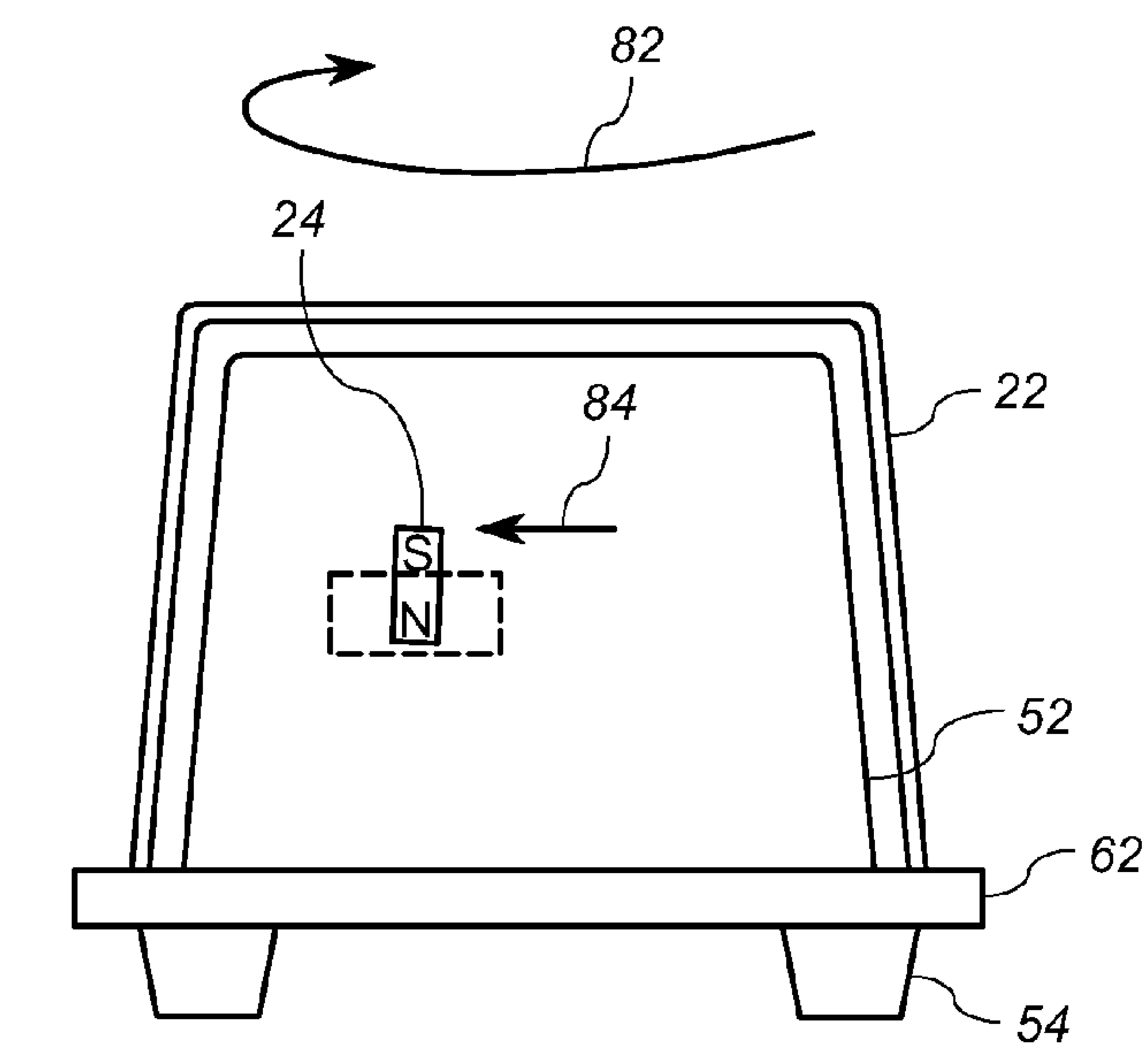



FIG. 4

PRIOR ART

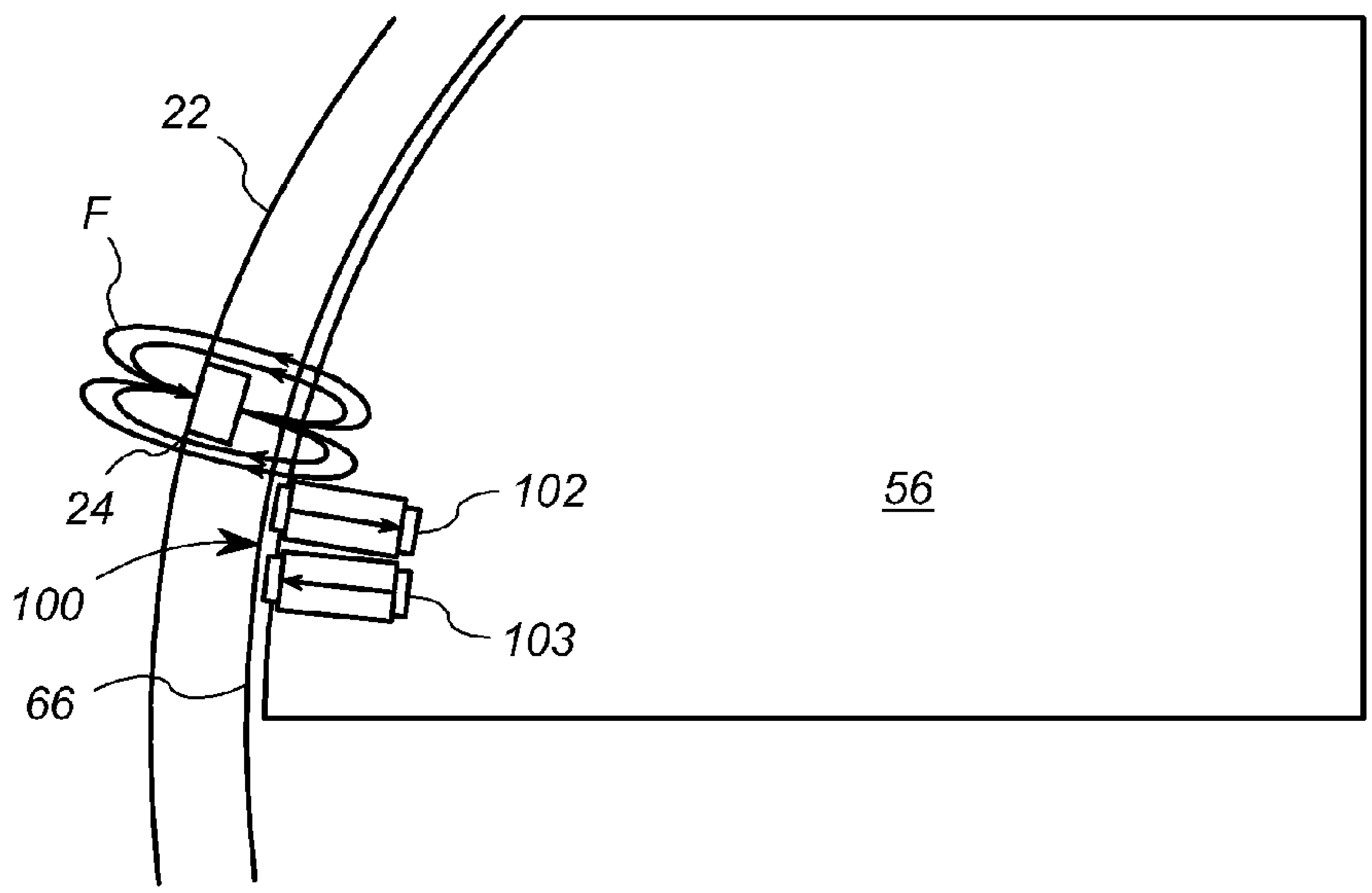



FIG. 5

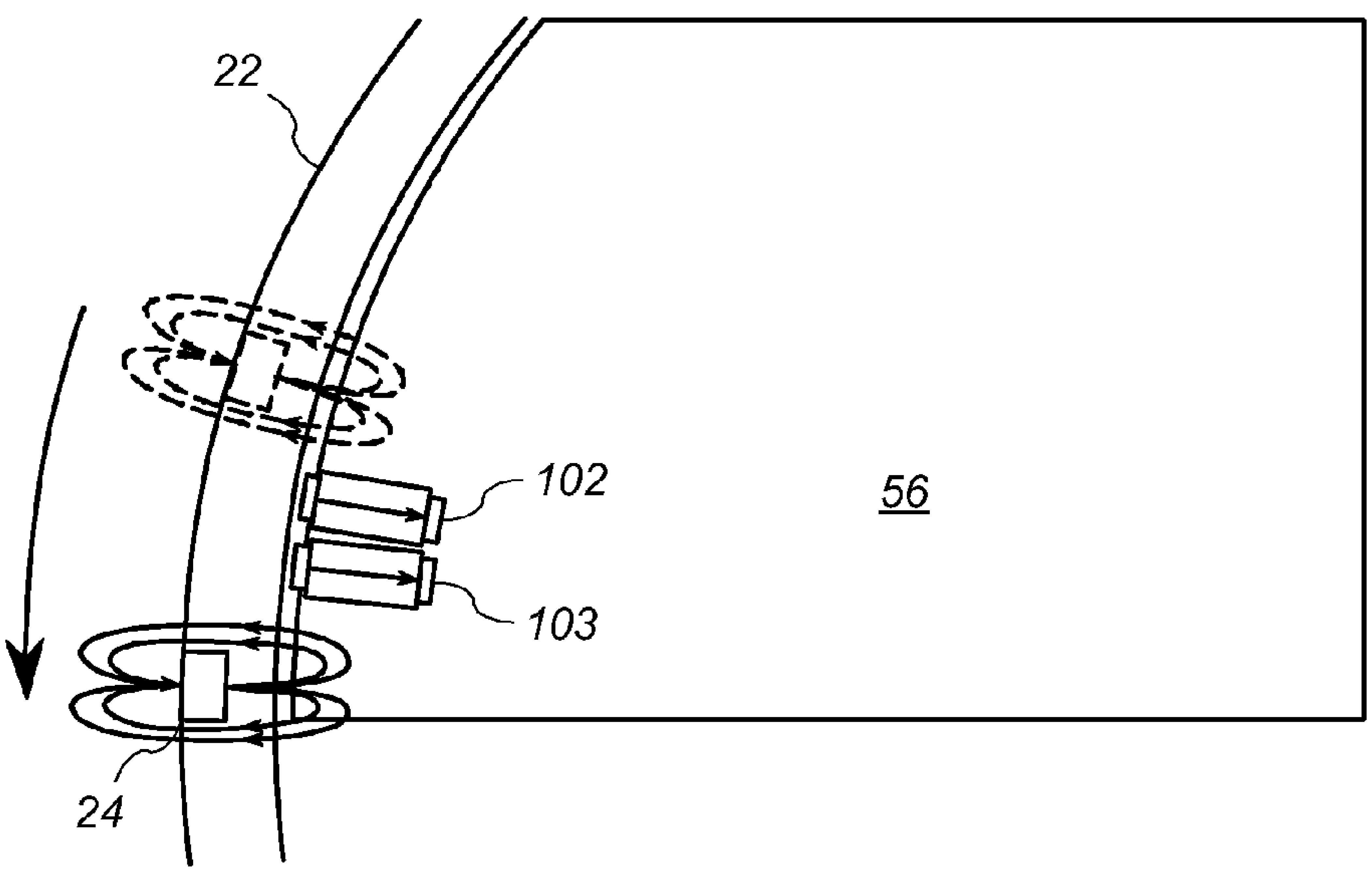



FIG. 6

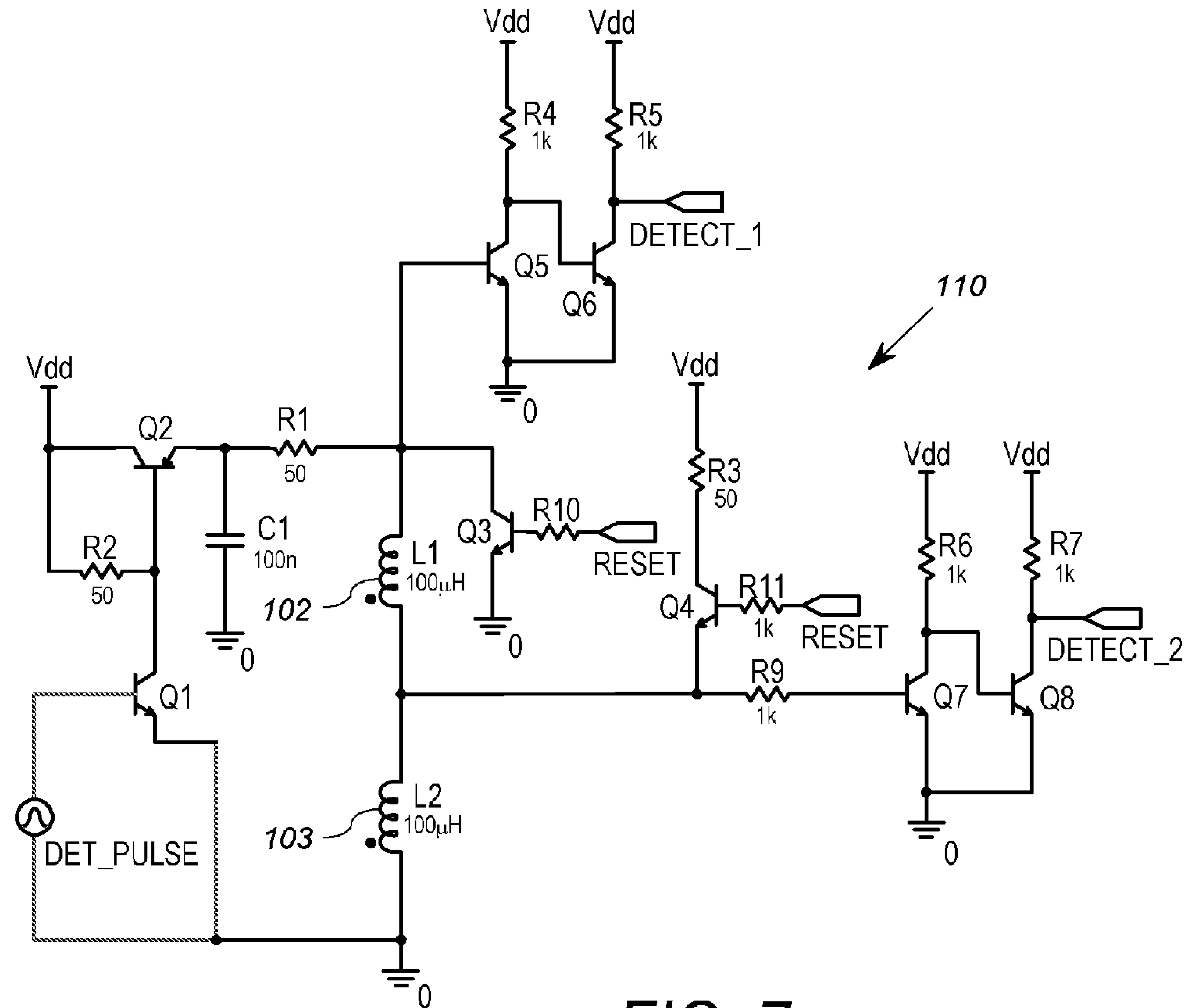



FIG. 7

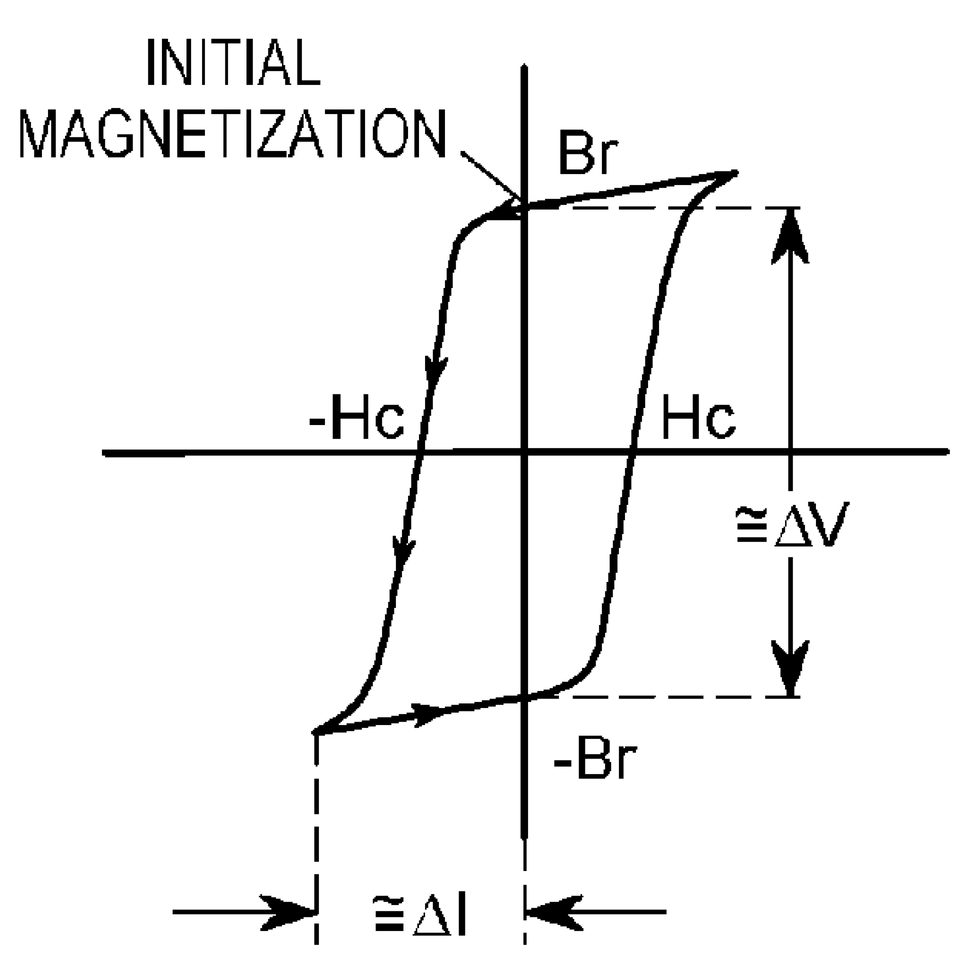



FIG. 8a

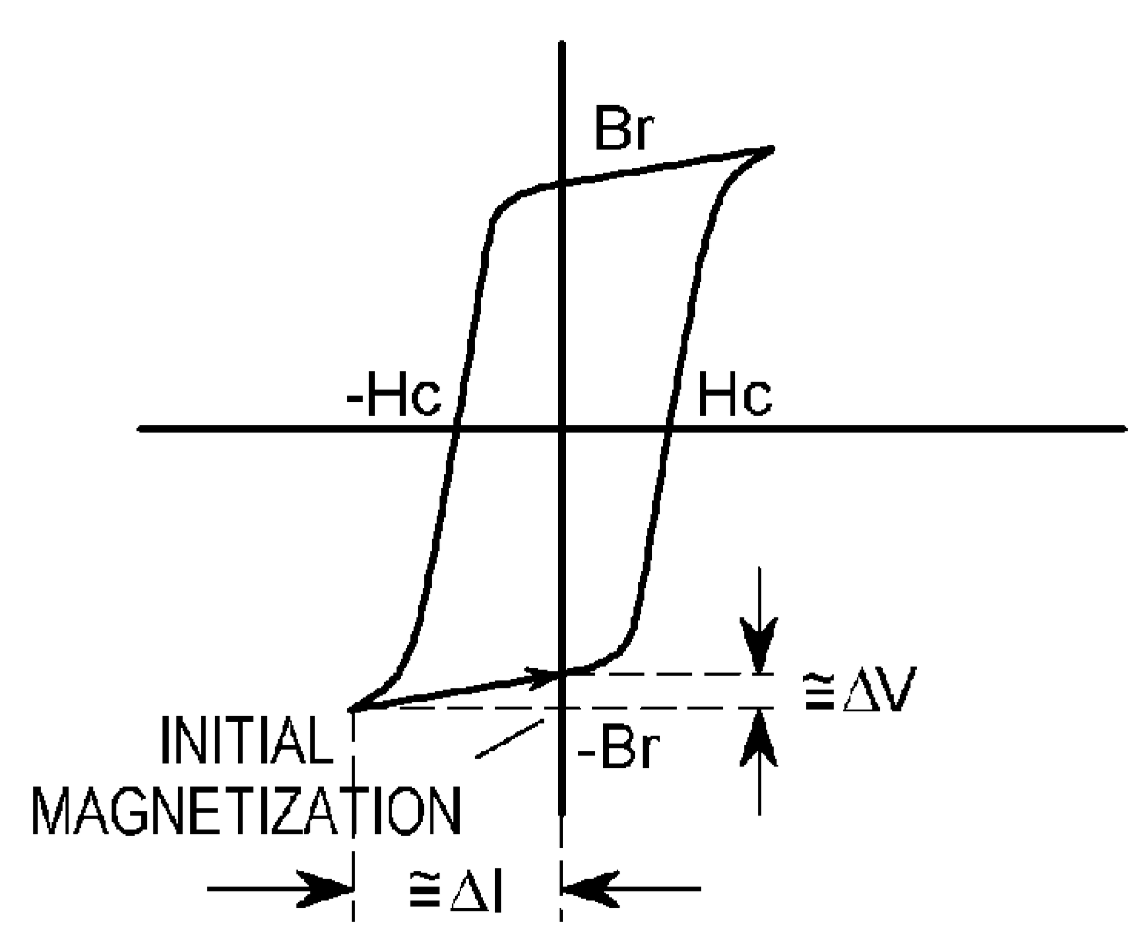



FIG. 8b

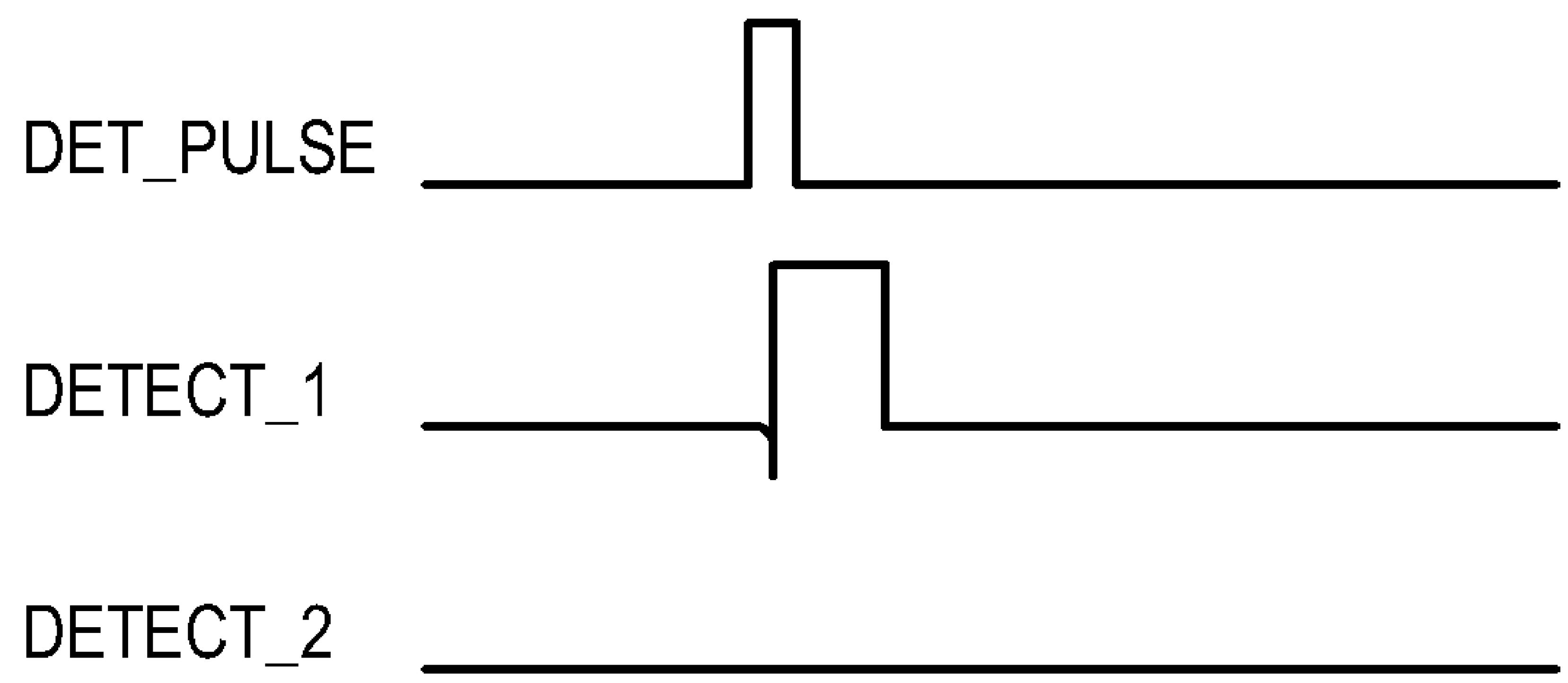



FIG. 9

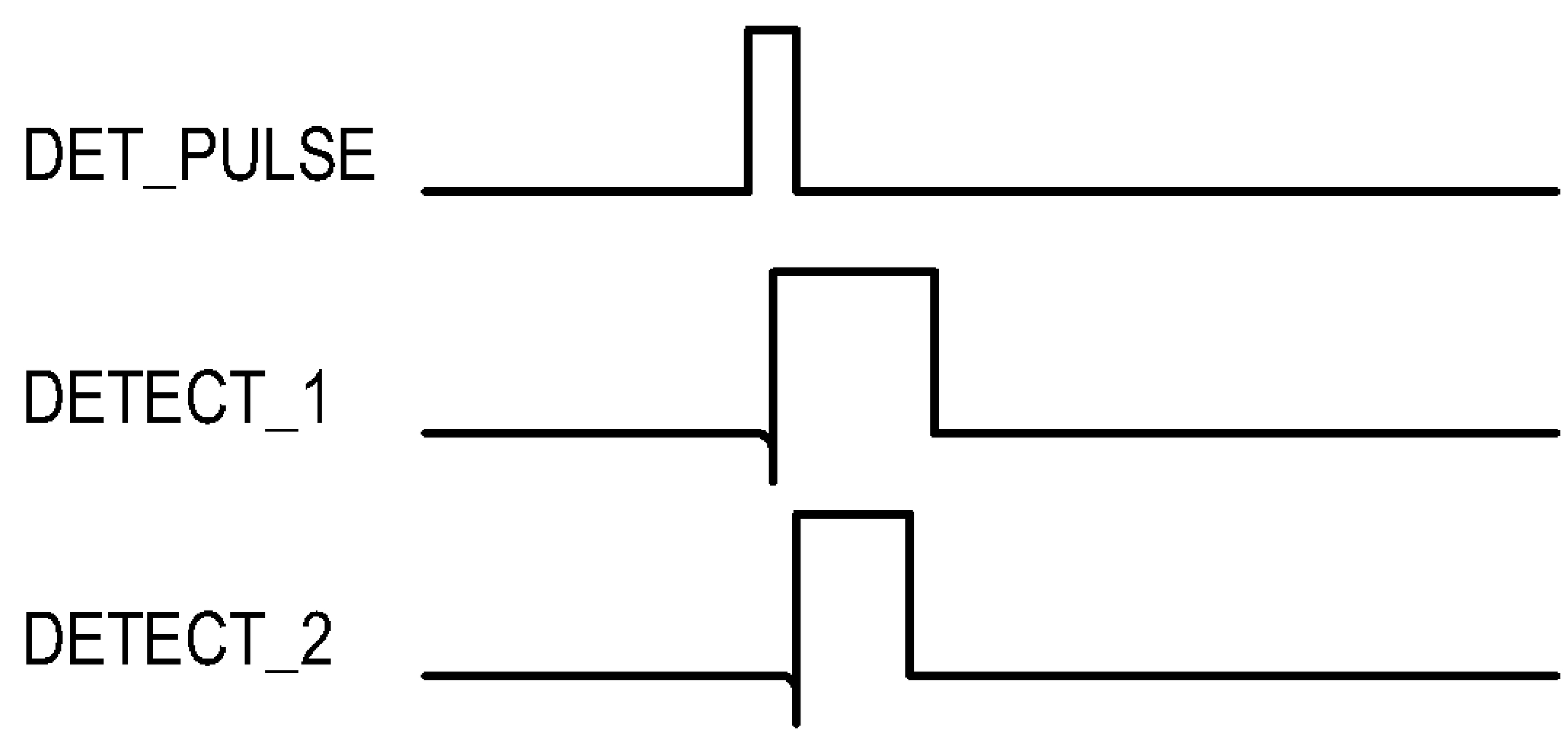



FIG. 10a

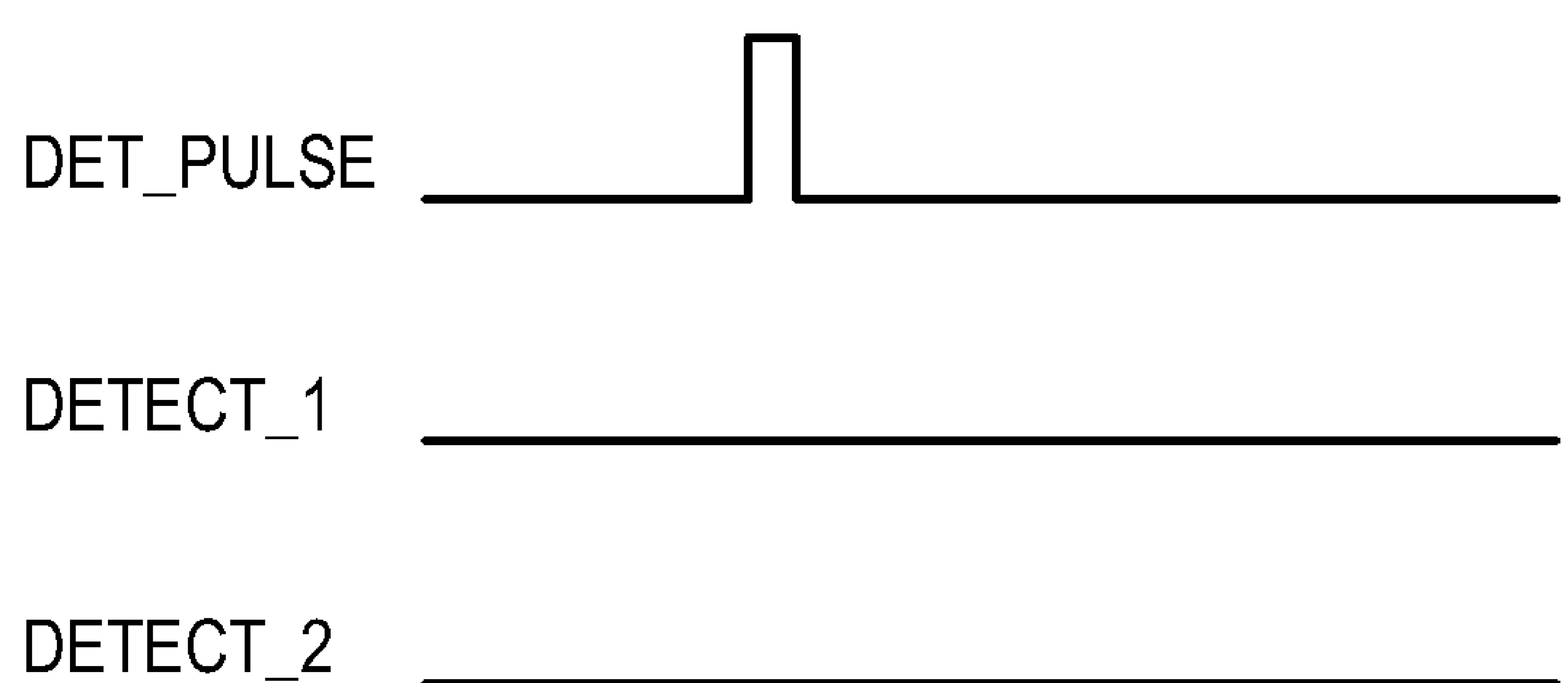



FIG. 10b

# ELECTRONIC TAMPER DETECTION IN A UTILITY METER USING MAGNETICS

## FIELD OF THE INVENTION

This disclosure relates generally to tamper detection in utility meters.

## BACKGROUND

There is a need for devices that detect tampering with utility meters. Tampering with utility meters can cause damage to equipment, serious injury, and loss of revenue. Meter tampering typically involves opening the sealed meter cover to either disable the counting/registration device or to divert a resource (such as water or electricity). By diverting the resource past the meter (i.e. bypassing the meter), the resource may be consumed without recordation or registration for billing purposes.

While meters are crafted in a way such that opening the meter cover is difficult, it is not practical or likely possible to create a meter cover that cannot be removed. Indeed, at least one consideration is that meter technician may be required to open the meter cover at some point. Therefore the meter closure cannot be impenetrable. Accordingly, a main strategy in tamper protection is to detect and flag a tamper event. Because meters are periodically read, either in person or remotely, the flagging of a meter tamper event allows for relatively timely indication that tampering has occurred. Upon receiving evidence of a tamper event, the situation can be corrected.

Traditionally, mechanical seals have been placed between the meter base assembly and its cover to inhibit unauthorized access. In such cases, a broken seal can indicate a tamper event. This protection mechanism, although sufficient on meters employing primary mechanical counters, may not provide adequate protection for electronic meters. In particular, electronic meters can often be read remotely or at least without close inspection of the meter. Accordingly, if an electronic meter has the ability to report metering data remotely, there may seldom be an opportunity for a meter technician to observe a broken seal at the location of the meter.

One approach to tamper detection is to place a position sensor on the meter cover. In particular, as is known in the art, electronic meters typically include processing circuitry. Such processing circuitry can record any movement of position of the sensor. However, this solution is only effective when the meter is powered, since the position sensor circuits otherwise lack bias power. Conceivably, a thief could tamper with the meter during a power outage without detection. If the thief replaced the meter cover before power is restored, the position sensor would never detect an issue.

There is a need, therefore, for improved electronic tamper detection that operates in the absence of meter power, and does not require, or at least rely exclusively on, a mechanical seal.

## SUMMARY OF THE INVENTION

At least some embodiments of the present invention address the above described need, as well as others, by providing an arrangement for use in a utility meter, comprising at least two magnetizable elements supported on a first meter structure, such as a meter base, and each configured to be magnetized to a first polarity and an opposite second polarity. A processing circuit is operably coupled to the magnetizable elements to determine the relative polarity of the magnetizable elements and to generate a tamper indication if the magnetizable elements have the same polarity. The arrangement further comprises a magnetic element supported on a second meter structure configured to be physically connected to the first meter structure, such as a meter cover, the magnetic element positioned such that removal of the second meter structure from the first meter structure causes the magnetic element to move past the magnetizable elements. The magnetic element is configured to cause the magnetizable elements to have the same polarity upon passage of the magnetic element.

In a further feature of the disclosed arrangement, the processing circuit is configured to magnetize the magnetizable elements in different polarities when the meter is closed and operational. The magnetizable elements may include inductors with a saturable core with the inductor windings electrically connected to the processing circuit. In certain embodiments the processing circuit may include a voltage divider circuit to which the inductor coils are connected. The voltage divider circuit may include logic elements capable of generating a logical output for each of the magnetizable elements indicative of the polarity of the element. In one aspect, the processing circuit includes a pulse generator for applying a pulse signal with a predetermined polarity to the voltage divider circuit, with the contribution of each inductor to the divided voltage being a function of the polarity of the inductor compared to the predetermined polarity of the pulse signal

The above described features and advantages, as well as others, will become more readily apparent to those of ordinary skill in the art by reference to the following detailed description and accompanying drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows a schematic block diagram of an exemplary electricity meter that incorporates an arrangement for detection according to the present disclosure;

FIG. **2** shows an exploded perspective view of an exemplary embodiment of the meter of FIG. **1**;

FIG. **3** shows a representative side view of a meter with a magnetic tamper detection feature, shown in a final position;

FIG. **4** shows a representative side view of a meter and magnetic tamper detection feature, shown in a non-final position;

FIG. **5** shows a top partial cut-away view of a meter and meter cover incorporating a magnetic tamper detection feature according to one aspect of the present disclosure, with the meter cover shown in a final position.

FIG. **6** shows a top partial cut-away view of the meter and meter cover shown in FIG. **5**, with the meter cover shown in a non-final position.

FIG. **7** shows a circuit diagram for voltage divider circuitry as part of the magnetic tamper detection feature shown in FIG. **5**.

FIGS. **8***a*, **8***b* show hysteresis loop diagrams for the inductors used in the magnetic tamper detection feature shown in FIG. **5**.

FIG. **9** shows a graph of the detection signals generated by the voltage divider circuitry shown in FIG. **7** in a normal, non-tamper operating condition of the magnetic tamper detection feature shown in FIG. **5**.

FIG. **10***a*, **10***b* show graphs of detection signals generated by the voltage divider circuitry shown in FIG. **7** in two tamper conditions.

## DETAILED DESCRIPTION

FIG. **1** shows an exemplary electricity meter **10** that incorporates an arrangement for tamper detection according to the invention. The electricity meter **10** includes measurement circuitry **12**, a processing circuit **14**, a display **16**, a sensor **18** and optical communication circuitry **19**, all disposed on or supported by or within a structure **20**. The meter **10** also includes a cover **22** having an embedded magnet **24**.

The measurement circuit **12** includes voltage and/or current sensors, analog to digital conversion circuitry, and other circuitry configured to generate digital measurement and/or energy signals from power lines, not shown. Such circuits for electronic meters are well known in the art. The processing circuit **14** is a circuit that performs control functions with the meter **10** and in many cases performs further processing on the digital measurement signals generated by the measurement circuit **12**. For example, the processing circuit **14** may convert raw digital measurement information into a format that is displayable, or convert energy information to derivative types of energy consumption information, such as those related to time-of-use metering and/or demand metering which are known in the art.

In another embodiment, the meter **10** includes a remote communication circuit, as is known in the art, and the processing circuit **14** would communicate metering data to a remote location via such a communication circuit. It will be appreciated that the exact physical configuration of the measurement circuit **12** and the processing circuit **14** is not central to the implementation of the invention, and this embodiment of the invention may be used in a wide variety of meters that include digital processing circuitry. While the processing circuit **14** includes the specific additional functionality related to tamper detection described herein, it may otherwise include known processing circuit structures and functionalities. Suitable embodiments of the measurement circuit **12** and such a processing circuit are described, for example, in U.S. patent application Ser. No. 12/777,244 filed May 10, 2010, Ser. No. 12/537,885, filed Aug. 7, 2009, and Ser. No. 12/652,007, filed Jan. 4, 2010, all of which are incorporated herein by reference.

The display **16** in this embodiment is an LCD display **16** that provides visible display of information as controlled by the processing circuit **14**. Such display devices are known in the art and may take many forms.

In a prior tamper detection system, the sensor **18** is a bi-stable magnetic switch, as disclosed in commonly-owned application Ser. No. 13/225,154 [hereinafter "the '154 application"], entitled "Electronic Tamper Detection in a Utility Meter Using Magnetics," filed on Sep. 2, 2011 and published on Mar. 29, 2012, as Pub. No. 2012-0074927 A1, the entire disclosure of which is incorporated herein by reference. As disclosed in the '154 application the bi-stable magnetic switch is configured to controllably make or break an electrical connection based on sensing a particular change in magnetic field. Once in a particular position, the state of the switch does not change until the appropriate magnetic field is detected. As disclosed in the '154 application, the processing circuit **14** is operably connected to determine whether the bi-stable switch sensor **18** is in an open position or closed position. Thus, the processing circuit **14** can determine whether the sensor **18** has detected a particular change in magnetic field.

The structure **20** is a support structure for the meter **10** apart from the cover **22**. The structure **20** may include on or more printed circuit boards, and includes the base portion of the meter **10** in this embodiment. (See FIG. **2**). In general, when the meter cover **22** is removed from the meter, the structure **20** would be the physical support from which the meter cover **22** is removed.

Accordingly, the meter cover **22** is a physical structure that forms a protective cover over the electronic elements **12**, **14**, **16** and **18** supported by the structure **20**. The meter cover **22** is at least partially transparent to allow reading of the display **16**. In many cases, the cover **22** and the structure **20** include mating elements to facilitate securing the cover **22** onto the structure **20**. Such mating elements typically require at least some rotation of the meter cover **22** after it has been placed on a corresponding portion of the structure **20**. Meter covers that secure to a meter base via a rotational locking procedure are well known in the art.

In general, the meter cover **22** has a final, installed (or fully closed) position and a plurality of non-final positions on the structure **20**. The final position is associated with an installed and operating meter **10**. In such a case, the meter cover **22** is mated with the structure **20**. For example, if the meter cover **22** is threaded, then the final position is when the meter cover **22** is fully rotated to its maximum extent (fully closed position) on the structure **20**. In such a position, additional sealing elements may or may not be used to inhibit rotating the meter cover **22** in the opposite direction for the purposes of removal. A non-final position, as used herein, means any position of the meter cover **22** on the structure **20** that is not in the final position, such as, by way of non-limiting example, when the cover **22** is at any stage of rotation toward removal. To this end, FIG. **3**, described further below, shows the meter **10** with the cover **22** in final position, and FIG. **4** shows the meter **10** with the cover in a non-final position.

The magnetic element **24** is attached to an interior wall of the meter cover **22** and is generally disposed such that any removal of the cover **22** will cause the magnetic element **24** to pass by the sensor **18**. The magnetic element **24** is arranged in such a way as to pass through a position in which the magnetic element **24** is aligned at least in part with the sensor **18** to as to cause the sensor **18** to change its state if it is in a first state, but not in a second state. According to the system disclosed in the '154 application, if the sensor **18** has a first state from which only a north polar magnetic field can change its state, and has a second state from which only a south polar magnetic field can change its state, the magnetic element **24** is aligned such that removal of the meter cover **22** only causes one of the north or south polar magnetic fields to align with the sensor **18** sufficiently to switch the state of the sensor **18**.

FIGS. **2**, **3** and **4** show in further detail an exemplary mechanical arrangement of the meter **10** of FIG. **1**. FIG. **2** shows an exploded perspective view of a first embodiment of the meter **10**, while FIGS. **3** and **4** show side representations of the meter **10** of FIG. **2** in different stages of engagement and removal of the cover **22**.

As shown in FIG. **2**, the meter cover **22** is a largely cylindrical open bottom structure defining an interior **64** and having a main cylinder wall **66** and a bottom connecting portion **62**. It will be appreciated that the cylinder wall **66** may also have a slightly tapered or frustoconical shape. The bottom connecting portion **62** includes an annular shelf **63** extending outward from an open end (i.e. bottom) of the main cylinder wall **66**, and an annular skirt **65** continuing downward from an outer edge of the shelf **63**. The annular skirt **65** includes a threaded interior surface **67**. The threaded interior surface **67** has threading configured to rotatably engage corresponding threads **60** of the structure **20**, as will be discussed further below. The meter cover **22** also includes an optical port lens structure **58** configured to provide an optical link from exterior of the meter **10** to the optical communication circuitry **19** which is disposed in the interior of the meter **10**. In this embodiment, the meter cover **22** is transparent, and made from a polycarbonate material, which is known the art.

The magnetic element **24** is secured to the meter cover **22**, such as by an adhesive, in a position such that it exerts a first magnetic field in a radially inward direction with respect to the cylindrical wall **66**, as shown in FIG. **5**. The magnetic element **24** is disposed in a position such that it passes through the annular position of the sensor **18** when the threads **60**, **67** are engaged and the cover **22** is being rotated from the non-final position (or unsecured state) shown in FIG. **4** to the final position (or fully closed state) shown in FIG. **3**. The magnetic element **24** is further disposed such that it is not aligned with the annular position of the sensor when the cover **22** is fully rotated into the final position.

The structure **20** includes an interior cover **52**, a meter base **54**, and a circuit board assembly **56**. The interior cover **52** is also a largely cylindrical, open bottom structure defining an interior, not shown in FIG. **2**, but which would be readily apparent to one of ordinary skill in the art. The interior cover **52** is sized to fit within the interior **64** of the meter cover **22**, and is configured to be attached to the base **54**.

The circuit board assembly **56** is disposed within the interior of the interior cover **52**. The circuit board assembly **56** includes the processing circuit **14**, some or all of the optical communication circuitry **19** and a portion of the measurement circuit **12**. Elements of the measurement circuit **12**, such as for example, current coils, current transformers, and meter blades, are disposed on the underside of the meter base **54**, not shown. The interior cover **52** also supports the display **16**. The sensor **18** is mounted within the interior of the meter sufficiently close to the interior of cover **22** so as to allow the magnetic element **24** to actuate the sensor **18** when the magnetic element **24** is passed by the sensor **18**.

The meter base **54** includes a main plate **70**, an annular side wall **72**, and a lower annular skirt **74** having threads **60**. The annular side wall **72** extends downward from the main plate **70**, and the lower annular skirt **74** extends downward from the side wall **72**, although the skirt **74** may include a portion that extends partly radially outward from the side wall **72** as well, as shown in FIG. **2**. The annular skirt **74** and threads **60** are arranged such that the threaded portion **67** of the skirt **66** of the meter cover **22** engage threads **60**. This engagement is such that, when the meter cover **22** is rotated in the proper direction, the threads **60** and **67** cooperate to secure the meter cover **22** to the meter base **54**, and hence the structure **20**. It will be appreciated that additional elements may be used to prevent or inhibit movement (i.e. secure the meter cover **22**) once the meter cover **22** is in the final position.

The circuit board assembly **56** is secured to the main plate **70**. As discussed above, current sensors and other devices, not shown, but which are known in the art, are mounted to the underside of the main plate **70**.

FIGS. **3** and **4** show side views of the exemplary meter **10** of FIG. **2** fully assembled. FIG. **3** shows the meter **10** in the fully installed position, that is, in which the meter cover **22** is in its final position for ordinary ongoing meter operations. As shown in FIG. **3**, the magnetic element **24** in this case has first end **24***a* with a first polarity N and a second end **24***b* with a second polarity S, according to the system disclosed in the '154 application. Also show in phantom is the sensor **18** according to the tamper detection system disclosed in the '154 application, which is located inside the interior cover **52** and which would not normally be visible in a plan view.

In the fully closed position of FIG. **3**, the magnetic element **24** is axially aligned with (i.e. vertically on the same level as) the sensor **18**, but is not aligned with the annular or radial position with the sensor **18**. In this position, the magnetic field of the magnetic element will not activate the sensor **18**. It will further be appreciated that to remove the meter cover **22** from the base **54**, the meter cover **22** must be rotated in the clockwise direction **82**. When rotating in such direction, the magnetic element **24** moves in the direction **84** towards (and ultimately past) the sensor **18**.

FIG. **4** shows the meter **10** wherein the meter cover **22** has been partially rotated in the clockwise direction **82** as if to remove the meter cover **22**. As a result of this rotation, the magnetic element **24** moves such that it is at least temporarily aligned radially with the sensor **18**. As the magnetic element **24** passes to and through this position, the magnetic field causes the sensor **18** to change its state. Thus, in operation of the tamper detection feature, when the meter cover **22** is inserted on to the structure **20** (rotated onto the base **54** via the threads **60**, **67**), the magnetic field of the magnetic element **24** passes the sensor **18**, thus causing it so change state.

In the tamper detection feature disclosed in the '154 application, once the meter cover **22** is installed, an external magnetic element is passed over the bi-stable magnetic relay sensor **18** such that it changes the bi-stable state of the relay **18** to a state that will only change upon detection of a particular magnetic field polarity of the magnetic element **24**. This may be done as one of the final manufacturing or commissioning steps for the meter **10**, or any time after authorized service of the meter. In such condition, the meter **10** may then be installed in the field.

During normal operation, the processing circuit **10** detects the status of the sensor **18**. The sensor does not change state until it has been exposed to a significant magnetic field. In the system disclosed in the '154 patent, the magnetic field must also have a specific polarity to trigger the sensor because the sensor **18** also has a specific polarity.

If the meter **10** is tampered with, specifically, by removing the cover **22**, then the magnetic element **24** will pass over the sensor **18**, as shown in FIG. **4**, exposing the sensor to a magnetic field of the specific polarity. The only practical way to non-destructively tamper with the interior operations of the meter **10** is to remove the cover **22** by rotating the cover **22** in the open direction **82**. As shown in FIGS. **3** and **4**, moving the cover **22** in the direction **82** causes the magnetic element **24** to pass to its closest point to the sensor **18** which will necessarily cause the sensor **18** to change its state. The processing circuit **14** detects this change and records a tamper event.

In response to detecting a tamper event, the processing circuit **14** may suitably cause a display of a tamper indicator or code on the meter display **16**. In embodiments in which the processing circuit **14** is capable of remote communications, the processing circuit **14** can cause transmission of information indicating a tamper event to a remote device.

As thus far described, the tamper detection feature depicted in FIGS. **3** and **4** corresponds to the system disclosed in the '154 application. Since the sensor **18** in the system of the '154 application is a bi-stable switch, specific polarities are necessary for the sensor and magnetic element. Moreover, as described above, the specific polarity of the sensor **18** must be established by an external magnet after the cover has been installed. Moreover, the bi-stable or Reed-type switch of the system disclosed in the '154 application can still be susceptible to tampering, albeit on a more sophisticated level than prior tamper detection systems.

In order to address these aspects of the bi-stable switch system disclosed in the '154 application, the present disclosure contemplates side-by-side inductors that can be "encoded". In accordance with one aspect of the present disclosure, a sensor **100** is provided within the cover **22** and in alignment with the magnet **24** mounted to the cover in a manner similar to the sensor **18** discussed above. The sensor **100** includes at least two helically wound inductors **102**, **103** that are supported immediately adjacent the cover so that the inductors can be influenced by the magnetic field F surrounding the magnet **24**, as illustrated in FIGS. **5** and **6**. The inductors **102**, **103** are immediately adjacent each other in close proximity so that the magnetic field F must necessarily pass over both inductors. The inductors **102**, **103** have a core with a high reluctance and a high magnetic memory. In one specific embodiment the core of the inductors can be a chromium-oxide metal.

In one aspect of the invention, the inductors are magnetized to a specific different polarity. Thus, as illustrated in FIG. **5**, the inductor **102** may have a positive polarity while the inductor **103** may have a negative polarity. This polarity is maintained as long as the inductors are not exposed to a magnetic field. When the cover **22** is rotated for removal from the base of the meter, the magnet passes the sensor **100** so that the magnetic field passes over both inductors forcing them to have the same polarity. Thus, in the example shown in FIG. **6**, when the magnet **24** passes over the inductors both have a positive polarity. Circuitry within the meter, such as on the circuit board structure **56**, detects the common polarity and issues a tamper indication, as described in more detail herein.

An exemplary circuit for detecting the polarity of the inductors is shown in FIG. **7**. In particular, the coils of the inductors **102**, **103** are integrated into a voltage divider circuit **110**. A pulse (Det_Pulse) is provided to the circuit such that the impedance of the inductance is much greater than the impedance of resistor R**1**, with the pulse divided across the inductors **102**, **103**. An inductor magnetized in a polarity similar to the pulse will show a lower inductance and will not contribute to the divided voltage. On the other hand, an inductor magnetized at an opposite polarity to the pulse will show a maximum inductance and will thus represent a substantial component in the voltage divider circuit **110**. The outputs of the coils of the inductors **102**, **103** are at nodes S**1** and S**2**, respectively. Signals at these outputs can drive the base of a corresponding transistor Q**5** and Q**7** to provide logic signals at respective inputs Detect **1** and Detect **2** to a microcontroller. Thus, for an inductor of a different polarity than the pulse signal, such as the inductor **102**, the output signal S**1** provides a base voltage for the transistor Q**5** that is sufficient to drive the transistor, so the output Detect **1** shows a logical "1". Alternatively, for an inductor, such as inductor **103**, of the same polarity as the pulse Det_Pulse, the output signal S**2** provides a base voltage to the transistor Q**7** that is insufficient for saturation of the transistor, so the output Detect **2** shows a logical "0". The microcontroller, which may be integrated into the circuit board structure **56**, the measuring circuit **12** or the processing circuit **14**, polls the logic signals Detect **1**, Detect **2** upon powering up the meter and periodically thereafter. Exemplary signals for a properly encoded meter that has not been tampered with are shown in FIG. **9**.

It can be appreciated that when the cover **22** is closed on the meter and the inductors have been encoded with different polarities, as illustrated in FIG. **5**, the logic signals at Detect **1** and Detect **2** will be different because only one of the inductors will essentially contributing to the divided voltage, as explained above. As long as the signals remain different no tampering is indicated. However, once the magnet **24** passes the inductors, the both move to the same polarity and the voltage divider circuit **110** will produce signals at S**1** and S**2** that are substantially equal, resulting in logic signals at Detect **1** and Detect **2** that are the same. When Detect **1** and Detect **2** are the same the microcontroller generates a tamper signal, as described above in connection with the sensor **18**. Exemplary signals indicative of tampering are shown in FIGS. **10***a* and **10***b*.

The microcontroller is thus configured to analyze the signals Detect **1** and Detect **2** as set forth in the following table:

| Stimulus | S1/Detect1 | S2/Detect 2 | Result |
|---|---|---|---|
| None | High | Low | No tamper detected. Magnetization polarities are unchanged |
| External Magnet Positive Polarity | High | High | Tamper detected. |
| External Magnet Negative Polarity | Low | Low | Tamper detected. |
| Cover removed | Low | Low | Tamper detected |
| Heating of Inductors | High | High | Tamper detected. |

It is noted that the last stimulus relates to tampering in which the inductors are heated to essentially demagnetize the cores. Given the proximity of the inductors to each other it is not likely that one inductor can be heated without heating the other. However, since the inductors are encoded to different polarities, changing the polarity of only one inductor means that both inductors will have the same polarity and tampering will be detected by the microcontroller.

The inductors **102**, **103** can be set to a specific polarity by saturating the inductor with a DC signal in the desired direction of polarity. For instance, the inductor **102** can be set by applying a signal at the Reset line to the transistor Q**3**, while the inductor **103** can be set at a desired polarity by a signal at the Reset line to transistor Q**4**. The Reset signal is applied for a time sufficient for a voltage at to the coil to saturate the inductor core material. Maximum inductance corresponding to a positive polarity in an inductor is shown in hysteresis loop of FIG. **8***a*, while the minimum inductance and a negative polarity is shown in hysteresis loop in FIG. **8***b*. The microcontroller is configured to apply a different polarity DC signal to each of the Reset lines to drive the two inductors **102**, **103** to opposite polarity. It can be appreciated that this action cannot be accomplished with the cover **24** removed or disengaged from the meter because once the cover is restored to its closed final position shown in FIG. **5** the magnet **24** must traverse the inductors, which necessarily will force the inductors to the same polarity. Moreover, the inductors cannot be saturated form outside the meter and cover **22** such as by placing a magnet in proximity to the sensor **100**. The inductors **102**, **103** are in very close proximity so that attempting to saturate one inductor will necessarily cause the magnetic field to intersect the other inductor. The tampering detection system of the present invention provides that the only method of encoding the polarities of the inductors is by an internal microcontroller (via the Reset lines) when the meter is closed.

The sensor **100** disclosed herein provides the advantage of not requiring power to the inductors to maintain them in their encoded polarities. Moreover, the inductors need not be powered in order to respond to a tampering attempt. The magnetic cores of the inductors respond to passage of a magnet or external heating to assume same polarity, whether positive or negative. Once the meter is powered again the microcontroller polls the Detect **1** and Detect **2** lines and the logic signals at these lines will be determined by the voltage divider circuitry **110** as explained above. The tamper indication feature may be disabled by an authorized party, whether remotely for wireless connected meters or via the optical port. The encoding of the inductor polarities may also be activated or accomplished remotely or via the optical port.

In the illustrated embodiment the sensor **100** is formed by two inductors. The inductors may be surrounded by magnetic shielding to prevent interference from an extraneous EMF source and to further limit the ability to somehow focus a magnetic field on individual inductors.

In one modification, the polarity of the inductors may be determined using a Hall-effect sensor positioned at the inner end of each inductor. The polarity of the voltage output of the Hall-effect sensor is indicative of the polarity of the inductor. In this instance, the voltage divider circuitry **110** would not be required.

In another modification, more the sensor **100** may be include more than two inductors with more than two bits of information provided to the microcontroller. More than two inductors can provide tolerance for error, such as if an inductor fails in some manner or somehow changes polarity when no tampering has occurred. For multiple inductors the microprocessor may be calibrated to acknowledge a certain threshold of changed polarities as an indication of tampering. Moreover, providing multiple inductors around the inner circumference of the cover **22** can make it virtually impossible to externally control the polarity of any individual inductor.

The above describe embodiments are merely exemplary. Those of ordinary skill in the art may readily devise their own implementations and modifications that incorporate the principles of the present invention and fall within the spirit and scope thereof. For example, it will be appreciated that a similar technique may be employed in a water or gas meter, if such meter includes digital processing circuitry.

What is claimed is:

**1**. An arrangement for use in a utility meter, comprising:

two magnetizable elements supported on a first meter structure and each configured to be magnetized to a first polarity and an opposite second polarity;

a processing circuit operably coupled to the two magnetizable elements to determine the relative polarity of the two magnetizable elements to generate a tamper indication if the two magnetizable elements have the same polarity; and

a magnetic element supported on a second meter structure configured to be physically connected to the first meter structure, the magnetic element positioned such that removal of the second meter structure from the first meter structure causes the magnetic element to move past the two magnetizable elements, the magnetic element configured to cause the two magnetizable elements to have the same polarity upon passage of the magnetic element.

**2**. The arrangement of claim **1**, wherein each of the two magnetizable elements is configured to maintain its respective polarity without external power.

**3**. The arrangement of claim **1**, wherein said first meter structure includes a base and said second meter structure includes a meter cover configured to be removably engaged to said base.

**4**. The arrangement of claim **3**, wherein:

the meter cover and base are provided with a threaded engagement configured for rotatable engagement of the cover to the base to at least partially secure the cover thereto; and

the magnet element and two magnetizable elements are arranged so that the magnet element moves past the magnetizable elements upon rotation of said cover relative to said base.

**5**. The arrangement of claim **4**, wherein:

said meter cover has a final position and a plurality of non-final positions on said base; and

said magnetic element is radially aligned with the two magnetizable elements only when said cover is in one of the plurality of non-final positions.

**6**. The arrangement of claim **1**, wherein the two magnetizable elements are inductors having a magnetizable core.

**7**. The arrangement of claim **6**, wherein the processing circuit includes:

a voltage divider circuit with each branch of the voltage divider circuit connected to an inductor of a corresponding one of the two magnetizable elements; and

a pulse generator for applying a pulse input signal having a predetermined polarity to each branch of the voltage divider circuit.

**8**. The arrangement of claim **7**, wherein the voltage divider circuit is configured such that an inductor magnetized to the same polarity as the predetermined polarity of the pulse input signal does not contribute to the divided voltage in the circuit, and an inductor magnetized to a different polarity than the predetermined polarity generates a substantial contribution to the divided voltage.

**9**. The arrangement of claim **7**, wherein the processing circuit includes logic elements configured to convert the divided voltage into logic signals.

**10**. The arrangement of claim **9**, wherein the logic elements include a transistor associated with each branch of the voltage divider circuit, with the base of the transistor driven by a voltage output from a corresponding inductor.

**11**. The arrangement of claim **1**, wherein the processing circuit is configured to selectively magnetize each of the two magnetizable elements.

**12**. The arrangement of claim **11**, wherein:

the two magnetizable elements are inductors having a magnetizable core; and

the processing circuit is configured to apply a voltage to the coil of the inductors sufficient to saturate the magnetizable core.

* * * * *